Indian J.Sci.Res. 14 (1): 114-121, 2017 ISSN: 0976-2876 (Print)
ISSN: 2250-0138 (Online)

INSPECTING THE BEHAVIOR OF INSULATED CONCRETE FORM (ICF) BLOCKS WITH POLYPROPYLENE SHEET

A. ARUN SOLOMON[a1], J. VINOTH[b], R. SUDHAKAR[c] AND G. HEMALATHA[d]

[a]Assistant Professor, Department of Civil and Mechanical Engineering, Karunya University, Coimbatore, India
[bc] Undergraduate Student, Department of Civil and Mechanical Engineering, Karunya Univesity, Coimbatore, India
[d]Associate Professor, Department of Civil and Mechanical Engineering, Karunya University, Coimbator, India

ABSTRACT

Insulated Concrete Form (ICF) is an emerging construction technology using the interlocking of Expanded Polystyrene (EPS) sheet with poured in place concrete. This technique has numerous advantages over traditional brick wall and RCC construction. It provides energy saving and energy efficient building, needs no special form works, cost effective, fastest way of construction, sound proof, less maintenance, disaster resistance, etc., One important aspect need to be analyzed is that internal and external finishing of the Expanded Polystyrene material. Because Expanded Polystyrene material provides high thermal resistivity and increase energy efficiency and thermal comfort of living. Even though the material has very less hardness and toughness property, hence the structure cannot be left as it is, the EPS material should not expose to the atmosphere to increase the life of the structure. This paper deals with the compression behavior of Insulated concrete form blocks finished with polypropylene sheets. 60 mm, 100 mm thick EPS material and 6mm thick polypropylene sheets have been used to cast molds and to conduct experiments. The results indicate that finishing material doesn't contribute to increase the compressive strength and the nature of the failure is brittle. But the high properties of hardness and toughness, it is recommended polypropylene sheets as a finishing material.

KEYWORDS- EPS Sheet, Insulated Concrete form, Load-Deflection Curve, Polypropylene Sheet

Growth of population leads to increase in construction of residential and commercial building. India is facing problems like shortage of construction building materials. Hence the challenge faced by civil engineers is to develop new materials for the future. EPS (Expanded Polystyrene) sheets made from expandable polystyrene, which is a rigid cellular plastic containing an expansion agent. It has been tested by many researchers as an allowable light material for wall construction.

Insulating Concrete Forms (ICFs) are hollow molds with a center cavity (Figure 1) that is filled with reinforced concrete. The forms are usually made of rigid polystyrene or polyurethane insulation, and are produced as either pre-formed interlocking blocks, or as separate panels connected with plastic or steel rods and ties.

ICF structures are built by fitting together the insulating forms, adding steel reinforcing bars (rebar) for strength, and then filling the central cavity with concrete. The insulating forms, rebar, and concrete walls stay in place as a permanent part of the wall. The outer surface of the walls creates a supportive backing for most conventional finishing materials such as stucco.

LITERATURE SURVEY

M. A. Mousa and N. Uddin studied buckling behavior of Composite Structural Insulated wall panel (CSIP). Here, the author used low cost thermoplastic orthotropic glass/polypropylene (glass-PP) laminate as a face sheet and expanded polypropylene foam as a core. Investigations on the behavior of CSIPs under concentric and eccentric load were carried out. Global buckling was observed when experimental investigations were carried out with sample size of 101.6 x 76.2 x 34.48 mm. Analytical expressions for concentric and eccentric loading to validate the experimental results were developed and found both results were in good agreement. Design graphs for global buckling that can be used for preliminary design of the composite structural insulated panel under concentric and eccentric loading were also developed.

Figure 1: Typical ICF Block

In 2012, M. A. Mousa and N. Nuddin developed smaller scale experiments into large scale experiments. The size of the specimen was 1220 x 2440 x 147 mm and Pull off strength test was carried out to determine the bonding nature between cores and face sheet of CSIP panel made with different bonding agents. By the experimental results of Pull off strength test, it was concluded that spray adhesive is the best solution for manufacturing CSIP panels because of its high strength and low cost benefits when compared to other adhesives. CSIP panels designed to satisfy the design and deflection limits of ACI-318. The failure of the panel was by debonding between face sheet and the inner core.

[1]Corresponding author

C.A. Yahia and T. Majidzadeh experimentally investigated the identification of honeycomb in between the contact surface of EPS sheet. Ground penetrating radar was used to locate the honeycomb or voids in the Insulated concrete form structure. It was concluded that GPR was an effective method to detect voids in between EPS sheet and concrete, though smaller voids less than 18.75 mm were difficult to detect.

W. A. Friess et al. carried out research on the increase in energy demand of Dubai and the development of new technology of construction using EPS to reduce the energy consumption in terms of electricity usage in Dubai. The energy demand was studied using past 10 years record of electricity consumption in Dubai as well as model building of two storey semi detached single family villa was constructed that mostly resembles at Dubai's traditional construction. The building wall was constructed using standard mid plane insulated precast concrete blocks (200 mm) typically utilized in Dubai in that 60 mm Expanded Polystyrene (EPS) as used as a mid plane and 70 mm aerated concrete on both sides of EPS. As built villa is simulated with energy modeling software Design Builder (version 2.3.6) which uses the well tested Energy Plus (version 6.0) hourly simulation engine by one year of billed electricity consumption and infiltration data measured using a blower door tester. The extensive energy saving analysis was carried out using simulated Energy Plus model and U value was determined for the wall and RC frame with varying parameters and concluded that by Energy Utilization Index non-insulated block of 50 mm EPS can be preferred to decrease cost and increase thermal mass insulation over 30 % when compared to other models and the yearly energy consumption saving up to 20000 kWh per villa as well as reduction of CO_2 emission up to 7.6 tons per household can be achieved.

L. Smakosz and J. Tejchman examined experimentally the characteristics and behavior of composite structural insulated panels (CSIP) developed by Glass Fibre Reinforced Magnesia Cement Boards as face sheets and expanded polystyrene foam (EPS) as a core. The properties of used material in terms of compression, tension, bending and shear were tabulated. Various properties were examined through different test by using large and small scale specimens. It was found that CSIP panel has enormous potential in terms of crushing debonding and load bearing, however it was also mentioned that when compared to traditional Structural Insulated Panel (SIP) CSIP panels were failed by brittle nature.

From the study, it is understood that EPS can be a prime material for construction and many research are under progress with EPS, though ICF walls has limited research reports. ICF considered in this paper is fabricated using M25 grade concrete with three different densities of EPS is 4, 8, 12 kg/m^3 and two varying thickness of 50 and 100 mm. The compression and flexure properties of different densities of EPS were evaluated as per IS4671:1984. Compression behavior of ICF blocks made with different densities and varying thickness of EPS was examined using computerized universal testing machine. Bonding nature was analyzed using corrugated EPS and plain EPS. The results indicate that 12 kg density 100 mm thick EPS exhibits good ductile nature when compared to other ICF blocks, but there was not much variation in compression strength. EPS also displayed a high level of bonding with concrete without addition of any admixture.

Advantages

Insulation

ICFs provide very good insulation. The R-value (a measure of effectiveness as an insulator) of ICFs is typically rated R-18 to R-35, depending on the thickness of the wall. In comparison, traditional brick walls are usually rated R-10 to R-12.

Thermal Mass Effect

The mass of the concrete core of ICFs adds significantly to the thermal efficiency of the structure (Figure 2). The concrete acts as an energy reservoir and EPS sheet act as a energy barrier reducing temperature changes from day to night.

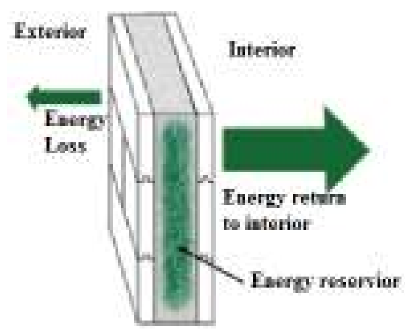


Figure 2: Thermal Mass Effect

Energy Efficiency

Homes built with ICFs typically require less energy to heat and cool than typical wood framed homes. This is due to higher R-values and reduced air leaks. Air leaks are associated with air infiltration, which impacts energy gain or loss in the structure.

Sound Proofing

ICF walls can help buffer the interior of a home from outdoor noise. Concrete is a material that tends to reflect noise, while foam insulation absorbs sound. The combination of foam and concrete creates a thick wall that serves as an excellent sound barrier.

Diasaster Resistance

ICF walls provide good resistance to storms, strong winds and seismic effects. According to tests performed at Texas Tech University, ICF walls were less likely to suffer damage in high winds than conventional houses. Additionally, the uniform thickness of ICF walls can help reduce drafts and cold spots associated with gaps in insulating material.

Less Maintenance

ICFs with foam insulation are resistant to rot and termite infestation, problems that are common in wood homes and costly to repair. Foam generally does not support mold growth which prefers wood over foam.

Simplicity

ICF structures are easy to build. ICF homes combine framing, installation of insulation, and sheathing into one step. An experienced contractor can construct an ICF home in less time than it would take to construct a wood conventional brick house, thus creating labor cost savings.

Flexibility

ICFs can be used with most conventional finishes or designs. Moreover, ICFs can easily be cut with a saw, so curves and odd angles are usually not a problem.

MATERIAL DATA

The main drawback in the construction using ICF is non availability of the required thickness and density of EPS sheets in Indian scenario. The manufacturer of EPS sheets produce only, if the requirement is mass and due to this the cost is comparatively high. The figure 3 shows two EPS sheets of thickness are 100 mm and 60 mm used in this project. The size of the sheet is 1000 x 500 mm. The physical properties of this material are given below

- Density : 6.37 kg/m3 for 60 mm thick EPS Sheet

  11.81 kg/m3 for 100 mm thick EPS

  Sheet
- EPS sheets absorbed more than 80 % of water, when the sample is immersed in water for 24 hours, but it regains its property immediately after drying.
- Compressive Strength: 0.8-1.6 Kg/cm
- Cross breaking Strength: 1.4-2.0 Kg/cm
- Tensile Strength: 3-6 kg/cm
- Self ignition point: 300 C

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids.

Polypropylene has a relatively slippery "low energy surface" that means that many common glues will not form adequate joints. Joining of polypropylene is often done using welding processes. Figure 4 shows typical polypropylene sheet which is used as a finishing material for ICF specimen.

MODELS PREPARATION

The EPS Sheets are cut into specified sizes. The specified size for the ICF model is 200 x 150 mm. Two pieces of such material is interconnected by 6 mm tor steel rods shown in figure 5. The steel was penetrated into the EPS Sheets by 40mm and gap of 60 mm was created between the two EPS sheets. In this cavity M20 grade concrete was poured. For comparison normal concrete without EPS also was prepared. The size of concrete model is 200 x 150 x 60 mm shown in figure 5.EPS sheets are covered by polypropylene sheets with suitable bolts. The bolts are penetrated through concrete; hence the possibility of separation from EPS sheets will not happen. For experiment plain concrete, 50 mm, 100 mm thick EPS as well as 6 mm thick polypropylene sheets have been used. Three plain concrete samples have been casted for comparison, three 50 mm thick EPS on both sides of concrete and three 50 mm thick EPS in addition to 6 mm thick polypropylene sheets with embedded bolts also casted. It is also done for 100 mm thick EPS sheets. Plain concrete also casted (figure 6)to compare the results.

Figure 3: Typical 100 mm 60 mm thick EPS sheets

Figure 4: Polypropylene sheet with embedded bolt

Figure 5: Typical casted ICF blocks with Polypropylene sheet

Figure 6: Typical casted Plain Concrete

Figure 7: Test setup in UTM

Figure 8: Typical Tested ICF Blocks with Polypropylene sheets

TESTING THE MODELS

After the ICF models are casted the samples are placed for curing. Because of huge water absorption property of EPS sheets, immersed curing method is not adopted. Instead of immersed curing moist curing by gunny bags is adopted. After 7 and 28 days compressive test was conducted in the universal testing machine. The deflection curve was plotted directly in the UTM machine. The figure 7 shows the compression test set up in 100 tonne UTM to test the ICF blocks.

EXPERIMENTAL OBSERVATION

The figure 8 shows the typical failure of ICF models. From the figure 9 to 14 it can be seen that even after the complete failure of concrete core part, the EPS sheets remains in an undisturbed condition and extends its load carrying capacity with prolonged deformation. It does not exhibit any cracks or any sort of disintegration. This phenomenon implies that, the formwork does not fail during peak load is very important in the construction industry, because this type of technology may be used in the seismic prone areas and other important structures to avoid spalling of concrete.

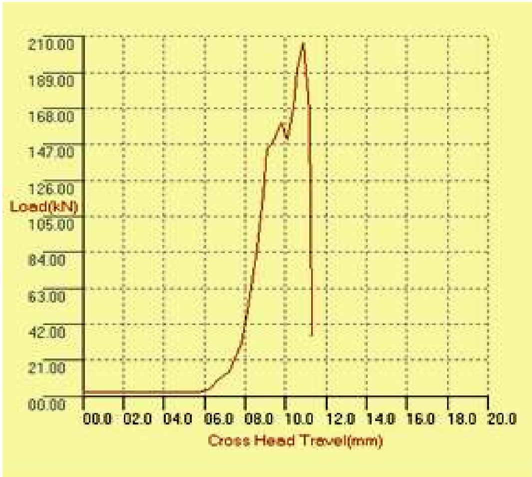
EXPERIMENTAL RESULTS AND DISCUSSSION

The compression test carried out for all the samples in the UTM meanwhile deflection chart also obtained. Table 1 gives the comparison of all the test results.

Table 1: Test Results

Sl. No.	Description of Specimen	Peak Load	Deflection at Peak Load	Maximum Deflection	Compressive Strength (28 Days) N/mm^2	Ref-figure No.
1	60 mm Thick plain concrete	207.7	10.9	11.4	17.31	15
		102.2	13.5	15.8	8.52	
		255.3	5.1	5.3	21.28	
2	50 mm Thick EPS sheet on either side of 60mm thick concrete	323.8	9.5	12.3	26.98	16
		218.6	11.3	21.2	18.22	
		304.9	9.3	17.9	25.41	
3	50 mm Thick EPS and 6 mm thick Polypropylene sheet on either side of 60 mm thick concrete	294.8	1.9	8.8	24.57	17
		350.6	12.1	16.2	29.22	
		310.2	5.5	8.9	25.85	
4	100 mm Thick EPS sheet on either side of 60mm thick concrete	409.4	11	14.2	34.12	18
		264.1	6.7	10.3	22.01	
5	100 mm Thick EPS and 6 mm thick Polypropylene sheet on either side of 60 mm thick concrete	338.2	4.5	10.6	28.18	
		418.5	8.3	16.8	34.88	

Chart 15 and 16 shows comparison of compressive strength and maximum deflection between various samples. It indicates the addition of 6 mm polypropylene sheet on either side of EPS sheet has increased compressive strength, but in the case of maximum deflection polypropylene sheet does not give much impact to the specimen, Even though the polypropylene sheet was suggested in the ICF system because of its water resistant, durability, easy to adopt and less cost.



Figurure 9: 60mm Thick Plain Concrete

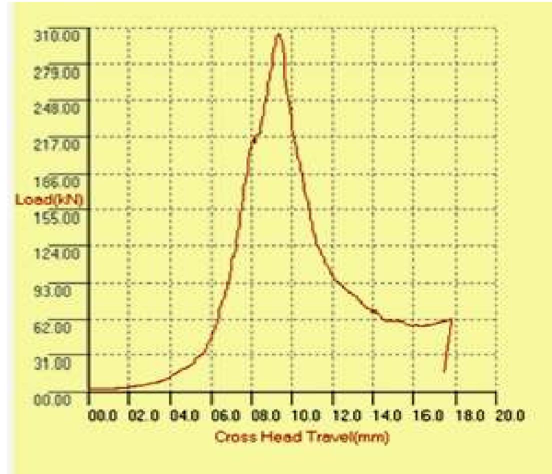


Figure.10. 50 mm Thick EPS sheet on either side of 60mm thick concrete

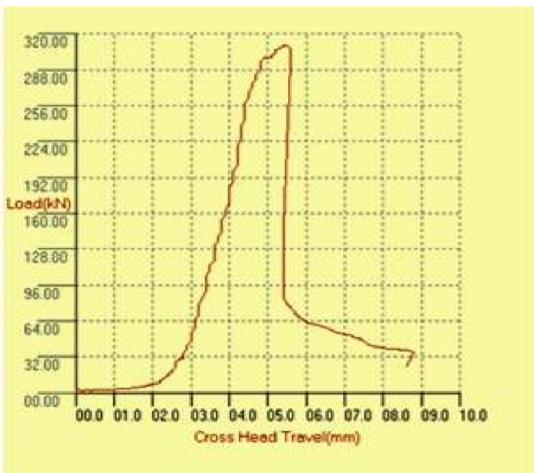


Figure 11: 50 mm Thick EPS and 6 mm thick Polypropylene sheet On either side of 60 mm thick concrete

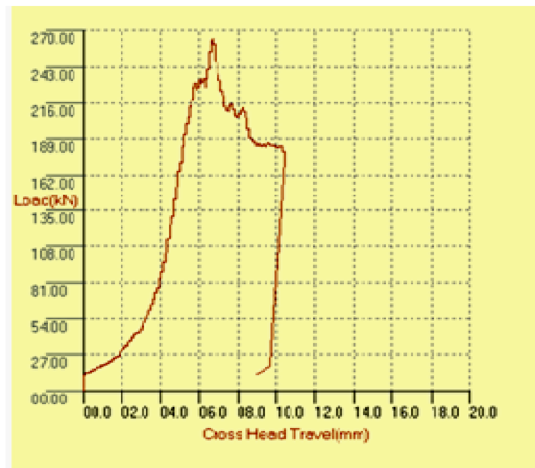


Figure 12: 100 mm Thick EPS sheet on either side of 60 mm thick concrete

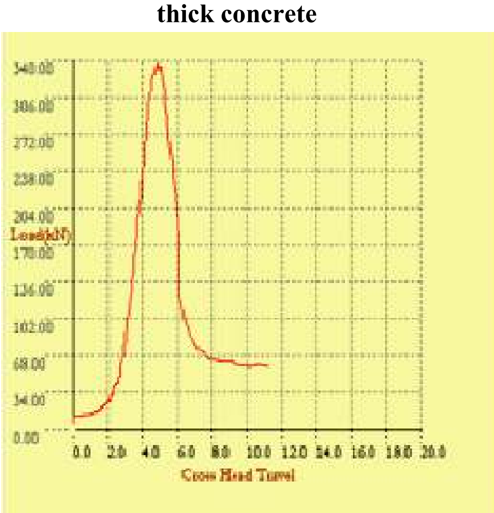


Figure 13: 100 mm Thick EPS sheet on either side of 60mm thick concrete

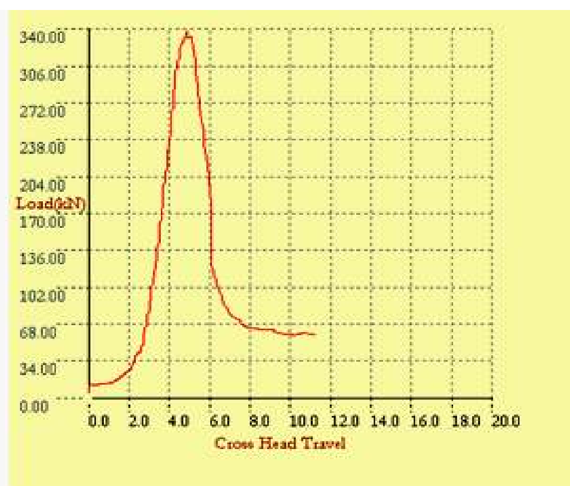


Figure14. 100 mm Thick EPS and 6 mm thick Polypropylene sheet on either side of 60 mm thick concrete

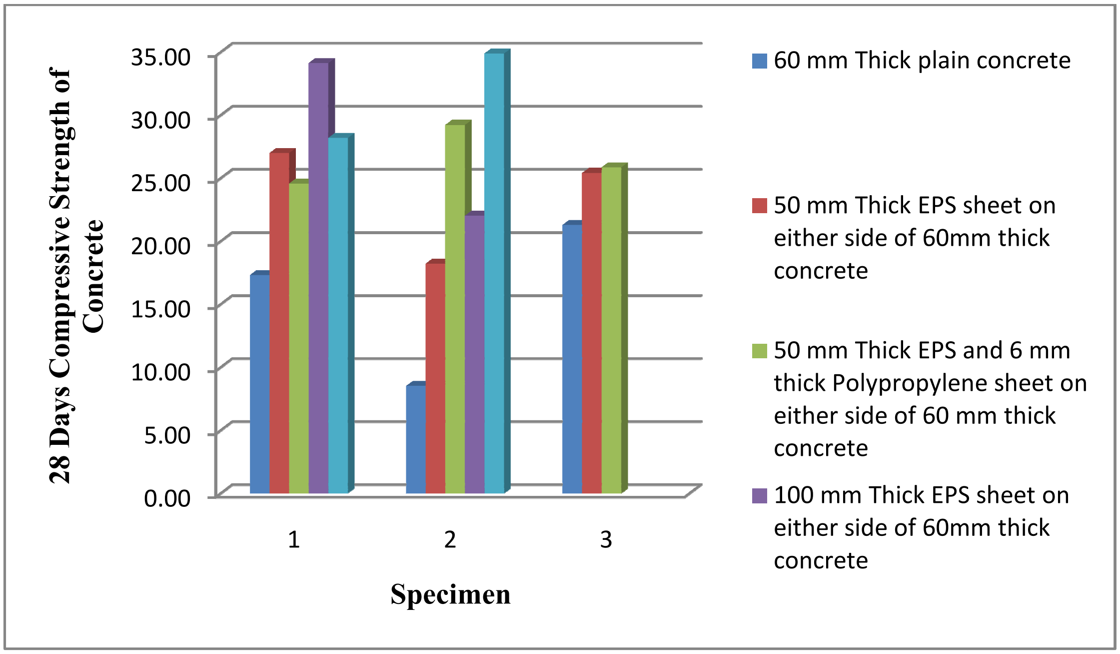


Figure 15: Compressive strength comparison chart

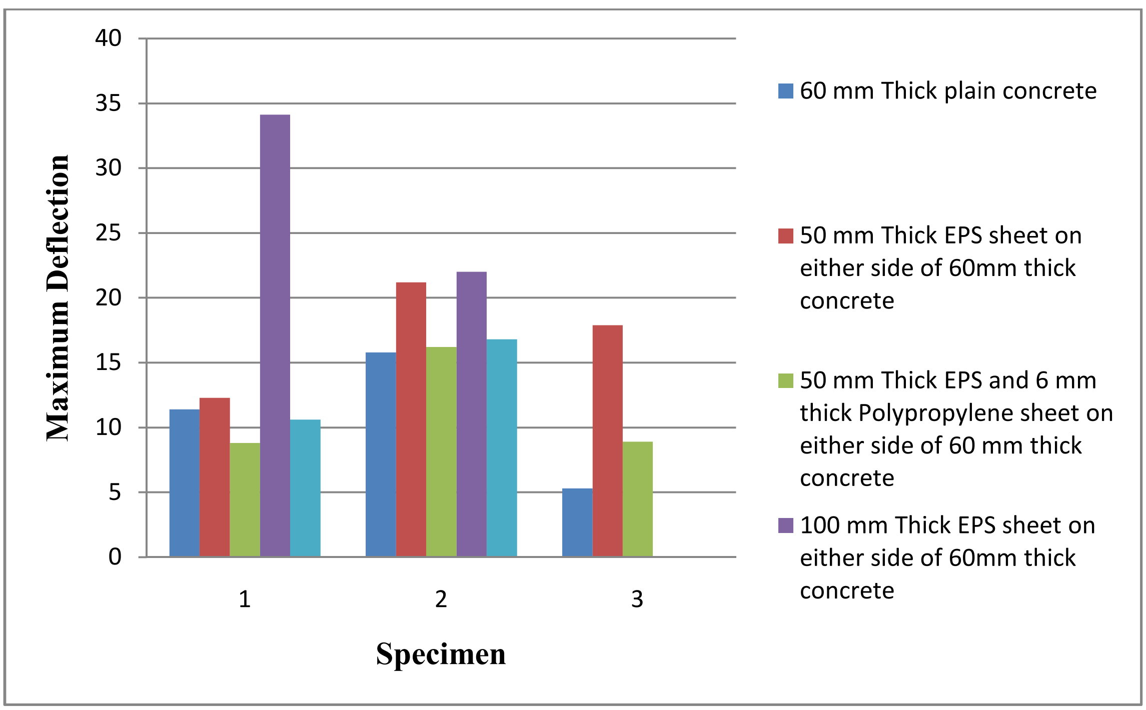


Figure 16: Maximum Deflection comparison chart

CONCLUSION

The following conclusions are obtained from the experimental analysis of Insulated Concrete Form with Polypropylene sheet

- Concrete specimen with EPS sheets exhibit, no cracking or zero disintegration of EPS sheets even after complete failure of concrete core. This means if walls are constructed with this method, the walls stands and deflect largely even though the load carrying concrete has failed.
- When compared to normal plain concrete and ICF model there is no much change in the load carrying capacity, but after attaining peak load sudden failure

occur in the normal plain concrete but ICF shows ductile failure.

- Polypropylene sheet has suggested for external and internal finishing of ICF system.
- Because of usage of EPS sheets, formwork is not necessary during construction; hence project time schedule will reduced. And it requires minimum skilled labors, leading to reduction in labor cost.
- Curing process is not required, since the concrete is covered by EPS sheets.
- Initial cost of ICF building is high for the reason that, non availability of required EPS sheets and concrete corer is the entire wall. But the building requires lesser amenities for heating and cooling, which may reduce the electric bill and it requires low maintenance
- Due to the ductile behavior its use may protect the structure from natural disasters like earthquake.

REFERENCES

Wensu Chen, Hong Hao, Dylan Hughes, Yanchao Shi, Jian Cui, Zhong-Xian Li, 2015. Static and dynamic mechanical properties of expanded polystyrene, Materials and Science, **69**:170-180.

CheirfAmer-Yahia and Todd Majidzadeh, 2012. Inspection of Insulated Concrete Form Walls with Ground Penetrating Radar, Construction and Building Materials, **26**:448-458.

Mohammed A. Mousa, Nasim Uddin, 2011.Global Buckling of Composite Structural Insulated Wall Panels, Materials and Design, **32**:766-772.

Mohammed A. Mousa and Nasim Uddin, 2012. Structural Behavior and Modeling of Full-Scale Composite Structural Insulated Wall Panels, Engineering Structures, **41**:320-334.

CherifAmer-Yahia and Todd Majidzadeh, 2012. Inspection of Insulated Concrete Form Walls with Ground Penetrating Radar, Construction and Building Materials, **26**:448-458.

Wilhelm Alexander Friess, KambizRakhshanb, Tamer A. Hendawib and Sahand Tajerzadehb, 2012. Wall insulation measures for residential villas in Dubai: A case study in energy Efficiency, Energy and Buildings, **44**:26–32.

Smakosz L. and Tejchman J., 2014. Evaluation of strength, deformability and failure mode of composite structural insulated panels, Materials and Design, **54**:1068-1082.

IS 10262:2009, Indian Standard, Concrete mix proportioning – Guidelines (fifth revision)

IS456:2000, Indian Standard, Plain and reinforced concrete – code of practice (Fourth revision)

IS 4671:1984, Indian Standard, specification for expanded polystyrene for thermal insulation purposes (First Edition).